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(54) **Tube formation method and apparatus**

(57) Methods and apparatus for forming products having at least one first section 102 having a first wall configuration and at least one second section 104 having a second wall configuration, the second wall configuration different from the first wall configuration. A variation in wall configuration along the axis of the tubular product 100 may be designed to be axially asymmetrical at any segment of the axis 101.

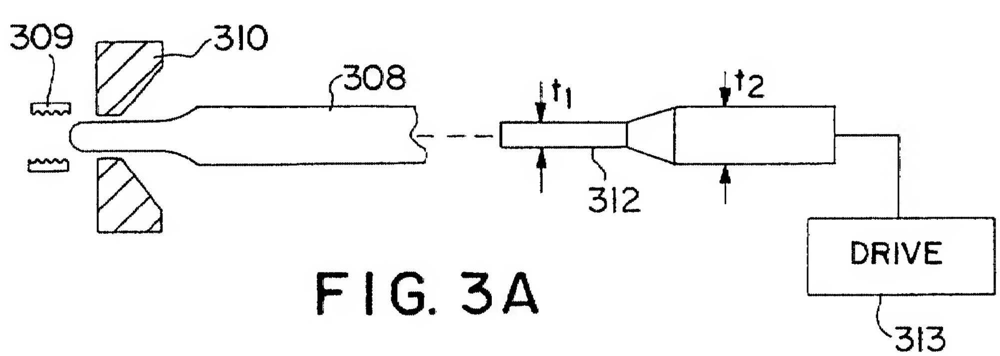


FIG. 3A

EP 1 177 843 A2

Description

FIELD OF THE INVENTION

[0001] The present invention generally relates to methods for forming tubular material.

BACKGROUND OF THE INVENTION

[0002] General methods for forming tubes or tubular structures are well-known. Included among these are methods for forming tubes that have varying wall thicknesses. Such tubes often find use in applications such as a starting material for hydroforming processes and for the formation of vehicle components, such as axle housings.

[0003] U.S. Patent No. 4,759,111 (TI Canada, Inc.) embraces the concept of welding sleeves on a tube at specific points and using the enhanced thickness to facilitate the hydroforming of certain shapes.

[0004] U.S. Patent No. 5,333,775 (General Motors) discusses several known processes for producing tubular parts of a variable wall thickness via hydroforming, and proposes a solution involving, initially, the fabrication of a tube blank of the desired longitudinal combination of wall thickness, perimeter and material by welding together portions of tubing having the desired characteristics and then hydroforming the resulting tube blank. Thus, similarly to the TI Canada patent discussed above, in the GM patent the thickness variation is obtained by welding segments of the tube with different wall thicknesses (and possibly even different material) in the segments themselves. This achieves substantially the same effect, as the sleeved tubes in the TI Canada patent, in hydroforming.

[0005] U.S. Patent No. 4,788,841 (Alcoa) involves a drawing process involving sinking, in which a tube is formed from a starting tubular piece while sandwiched part of the time between a mandrel and a die. A thicker wall ensues in portions of the final tubular product, which would appear to be a result of drawing the starting piece through a die without a mandrel, resulting in a wall thickness that is greater than that encountered in the starting piece (whereas a thinner wall ensues when the mandrel is used). However, this increase in thickness appears to be limited in magnitude and not precisely controllable.

[0006] It has been found that the processes discussed in the above-cited patents, as well as other known processes, can tend to be cumbersome to set up and carry out, or might not afford a degree of control that would otherwise be desired. In the case of the Alcoa patent, the fact that one or more final dimensions (such as one or more wall thicknesses) may not be precisely controllable leads to an undesirable and, sometimes, even untenable degree of uncertainty in forming tubular products.

[0007] A need has thus been recognized in conjunction with providing processes for forming tubes with varying wall thicknesses that avoids the disadvantages and shortcomings of conventional processes, including those discussed heretofore.

SUMMARY OF THE INVENTION

[0008] Broadly contemplated herein is a method for forming a one-piece hollow metal part of essentially any cross sectional shape *(e.g.,* circular, hexagonal, square, oval, etc.) that has at least two, deliberately provided, distinct wall thicknesses. This part could be a tube blank used as the starting piece for a subsequent hydroforming process or as a starting piece for the formation of a vehicle component, such as a vehicle axle housing.

[0009] Primarily, the formation of a monolithic tube is contemplated, which thus has no welding joints or other discontinuities that lie in a direction that is transverse to the longitudinal axis of the tube. (It will be understood that a "monolithic" tube, as the term is employed herein, does not rule out the inclusion of a seam and/or weld that is essentially parallel to the longitudinal axis of the tube, as is known in the tube-making arts. A "monolithic" tube could thus be a seamless tube, an electric resistance welded [ERW] tube with a weld line along the length or axis of the tube, or a drawn over mandrel [DOM] tube. All or any of these are essentially characterized by an absence of any weld-line or seam transverse to the axis of a tube or without any weld-line or seam around the circumference of the tube.)

[0010] Generally, at least one presently preferred embodiment of the present invention broadly embraces a method of making a tubular product, the method comprising: providing a starting hollow to be formed into a tubular product; providing a mandrel comprising: a first section having a first outer configuration; and a second section having a second outer configuration, the second outer configuration being different from the first outer configuration; and forming a tubular product from the starting hollow via interaction between the mandrel and the starting hollow.

[0011] Further, at least one presently preferred embodiment of the present invention broadly embraces apparatus for making a tubular product, the apparatus comprising: a mandrel for interacting with a starting hollow to be formed into a tubular product; the mandrel comprising: a first section having a first outer configuration; and a second section having a second outer configuration, the second outer configuration being different from the first outer configuration.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The present invention and its presently preferred embodiments will be better understood by way of reference to the detailed disclosure here below and to the accompanying drawings, wherein:

Figure 1 is a cross-sectional side view of a portion

of a tubular product showing two primary sections of varying wall thickness and associated transition section;

Figure 2 is a cross-sectional side view of a tubular product showing five primary sections of varying wall thickness and associated transition sections;

Figure 3A illustrates a formation assembly for forming a tubular product;

Figure 3B illustrates a mandrel used in the formation assembly of Figure 3A;

Figure 3C illustrates a mandrel for imparting three different thicknesses;

Figure 4A schematically illustrates a formation assembly employing discrete adjustment of the mandrel;

Figure 4B schematically illustrates a formation assembly employing the induction of vibration into one or more components;

Figure 4C schematically illustrates a formation assembly employing the heating or induction of portions of a tubular piece; and

Figure 5 is a cross-sectional view of a mandrel with a reverse spline outer configuration.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] Figure 1 illustrates a portion of a tubular product 100, with central longitudinal axis 101, that may be formed in accordance with an embodiment of the present invention.

[0014] As shown, tubular product 100 may have at least three sections, namely, a first section 102 having wall thickness **t**, a second section 104 having a greater wall thickness **T** and a third transition section 106. The longitudinal extent of each section 102, 104, 106, will preferably be chosen in a manner appropriate for the application at hand. Although steel is primarily contemplated as a material for tubular product 100, other metals are also conceivable for this purpose, such as aluminum, copper, titanium, alloys that include one or more of the above (including possibly steel) or alloys including other metals. Also possible for use as a material for tubular product 100 are non-metal materials such as plastics, fiberglass-reinforced plastics, or other reinforced carbon or plastic composites. It is also conceivable to form a tubular product that includes a combination of two or more of any of the aforementioned materials.

[0015] The tubular product 100 will preferably have a constant outer contour shown in Figure 1 as diameter D. Thus, varying wall thickness will result from varying inner diameters. Also, there is preferably radial symmetry about central longitudinal axis 101.

[0016] The number of distinct sections that a tubular product can have with the presently contemplated methods is limited only by the equipment and operating parameters being used.

[0017] Figure 2 illustrates a view of a tubular product 200, with a central longitudinal axis 201, having five distinct primary sections. Particularly, the main body 200 may have three types of primary sections, namely, three first sections 202 a/b/c having wall thickness **t** and two second sections 204 a/b having a greater wall thickness **T**. (Although a common thickness **T** is shown for sections 204a and 204b, it is to be understood that the thickness of section 204a may conceivably be different from thickness of section 204b.) As shown, the second sections 204 a/b are disposed between pairs of first sections 202 a/b/c. Similarly to the embodiment shown in Figure 1, there may be transition zones 206 a/b/c/d, respectively, between adjacent pairs of sections 202a/b/c and 204 a/b. Transition zones 206 a/b/c/d are preferably configured in a similar manner as the transition zone 106 discussed with respect to Figure 1. In each case, although a strictly linear transition between the two thicknesses is shown, it is to be understood that in reality an essentially non-linear transition may exist. As in the embodiment of Figure 1, **D** represents the overall outer diameter of tubular product 200 and there is preferably radial symmetry about central longitudinal axis 201.

[0018] It is to be understood that the tubular products 100, 200 illustrated in Figures 1 and 2 are provided merely for purposes of illustration. It is conceivable, within the scope of the present invention, to form a tubular product having a multitude of distinct main sections having differing wall thicknesses and differing contours for the inner and outer perimeters of the cross-section of the resulting product.

[0019] The disclosure now turns to a discussion of formation methods and formation assemblies that may be utilized in accordance with at least one embodiment of the present invention. First, a brief overview of some general considerations is provided.

[0020] The present invention broadly contemplates, in accordance with at least one presently preferred embodiment, drawing processes involving a multiple diameter mandrel. It should be appreciated that in drawing, the cross-sectional shape of a starting tubular hollow will be changed by deforming the hollow using tensile force, resulting in an increase in the length of the hollow. The tubular product cross-section eventually assumes its ultimate desired shape by forcing the wall of the hollow to pass between a die and the mandrel. The cross-sectional area of the metal in the finished product will be smaller than that of the starting hollow.

[0021] The presently contemplated processes, as is customary, also involve the initial selection of the ultimate parameters of the tubular product. Part of this se-

lection process will involve choosing the number of distinct sections desired, such as, sections with greater wall thickness, sections with lesser wall thickness and transition sections. The inner contours of the cross-sections of each section, length of each section and wall thickness within each section will also preferably be chosen in accordance with the application at hand.

[0022] As shown in Figure 3A, a formation assembly 300 includes a die 310 for accepting a tube 308, which in turn is to be disposed about, and interact with, a mandrel 312. A gripping assembly 309 (preferably part of a carriage not shown), as is known conventionally, will preferably be provided to grip the end of tube 308 so as to draw tube 308 through die 310. (Preferably, as shown, tube 308 will have been lubricated and "pointed" in known manner, thus facilitating initial insertion into die 308 and gripping of the "point" by gripping assembly 309.) Prior to a pointing process, the tube 308 may, in conventional manner, be lubricated so as to facilitate passage through the pointing machine as well as the die 310 . During a drawing process, the tube 308 will be drawn through die 310 and over mandrel 312. Die 310 will preferably have a strictly cylindrical or other selected interior surface and its opening will preferably have an inner diameter that is smaller than the outer diameter of tube 308. Further details on conventional drawing processes involving a mandrel and die would appear to be well known to those of ordinary skill in the art. (Reference in this connection may be made, for instance, to U.S. Patent No. 4,788,841 to Alcoa, incorporated by reference herein.)

[0023] Mandrel 312 preferably has two or more distinct diameters, in accordance with a preferred embodiment of the present invention. With joint reference to Figure 3B, a first section 314 of mandrel 312 may preferably have a diameter t_1 that is less than a diameter t_2 of a second section 316. An optional transition section 318 may be provided between sections 314 and 316.

[0024] Although, in Figures 3A and 3B, the bearing surfaces of the mandrel 312 and die 310 are indicated as generally being cylindrical in shape in most sections, it is to be understood that essentially any other shape or combination of shapes for bearing surfaces may be used.

[0025] For instance, splinular shapes and gear shapes, as well as polygonal shapes such as hexagonal and octagonal cross-sectional shapes are contemplated within the scope of the present invention.

[0026] Further, combinations of polygonal and/or other symmetrical shapes such as cylindrical, elliptical or even asymmetrical, shapes could be utilized for a mandrel. Thus, it is possible for a mandrel to be embodied by a part having a cross-section in which the outer perimeter is polygonally shaped while the inner perimeter is perhaps circular at one point along the longitudinal axis of the mandrel and another shape at another point along the longitudinal axis. This "other shape" at another point along the longitudinal axis could be elliptical or even of a polygonal shape that is distinct from that assumed by the outer perimeter. As a particular working example, for instance, the outer perimeter of a mandrel could have a rectangular or square cross-section while the inner perimeter is circular in cross-section at one point, elliptical at another and hexagonal at yet another, with suitable transition sections being provided in between the three cross-sectional configurations.

[0027] As shown in Figure 3A, a suitable drive 313 is preferably provided in order to move mandrel 312 along the direction of draw of the tube 308 while the tube is being drawn through die 310. As discussed below, this action of mandrel 312 assists in the formation of distinct sections in a final tubular product such as those illustrated in Figures 1 and 2. A hydraulic type of drive may be used for drive 313. Alternatively, an electrical, mechanical or electro-mechanical drive may be used.

[0028] The action of drive 313 will preferably be undertaken in such a manner as to controllably form thinner and thicker wall sections in tube 308 as tube 308 is being drawn. To form a thicker wall section of tube 308, mandrel 312 will preferably be positioned so that tube 308 is drawn over the smaller diameter mandrel section 314. In this connection, the free end of the smaller diameter mandrel section 314 will be positioned adjacent the opening of die 310. Conversely, to form a thinner wall section of tube 308, mandrel 312 will preferably be positioned so that tube 308 is drawn over the larger diameter mandrel section 316. In this connection, the forward end of the larger diameter mandrel section 316, that is, the end that meets transition section 318, will be positioned adjacent the opening of die 310.

[0029] It will thus be appreciated that, in connection with forming a tube 308 having two different thicknesses along its length, the thickness of a given section of the tube 308 will essentially be governed by the relative position of mandrel 312, and the constituent sections 314 and 316 thereof, with respect to die 310. To form two thicknesses in tube 308, then, mandrel 312 will essentially only need to displace between two different positions, namely, one which ensures that tube 308 will be drawn over smaller mandrel portion 314 as it enters the die 310 and another which ensures that tube 308 will be drawn over larger mandrel portion 316 as it enters the die 310. It will be appreciated that, whether a thicker or thinner section of tube is being drawn, the inner diameter of the tube 308 will be controllably held in check by virtue of the presence of mandrel 312, in stark contrast to those conventional arrangements (generally referred to as "sinking") in which a mandrel is not used when drawing thicker-walled sections of a tube, such as in the aforementioned U.S. Patent No. 4,788,841.

[0030] It will be appreciated that, if more than two distinct wall thicknesses are imparted onto a tube, and a mandrel 312' has three distinct sections 314', 316' and 317' of progressively increasing diameter (including a third, maximum diameter t_3, as shown in Fig. 3C), similar manipulations of mandrel 312' can take place as dis-

cussed above with relation to the two-stage mandrel 312. Thus, the presence of the smallest diameter mandrel section 314' at a die during the drawing of a tube will result in the thickest of three wall thicknesses in the tube, while the presence of the intermediate diameter mandrel section 316' at the die will ensure an intermediate one of the three wall thicknesses in the tube and the presence of the largest diameter mandrel section 317' at the die will result in the thinnest of the three wall thicknesses in the tube. As shown, two different transition sections 318' may be provided, respectively, between sections 314' and 316', as well as between sections 316' and 317'.

[0031] Returning to Fig. 3A, regardless of the number of distinct wall thicknesses intended to be imparted to a tube 308, the pattern of movement of drive 313 is preferably chosen in a manner appropriate for producing the intended final tubular product. Parameters that would be influential in this respect would include, for example, the length of travel of mandrel 312 in either direction and the duration that the mandrel 312 stays at a given position. Though the manner of governing these parameters is not restricted to any particular arrangement, an example of a suitable control apparatus would be a system of limit or proximity switches that, upon the carriage or gripper arriving at a given discrete position to impart a given wall thickness for a given section of tube 308, would ensure that the mandrel 312 does not travel further. Though a manual arrangement could be used to prompt the actual movement of a mandrel away from any static position, and automatic arrangement is also contemplated within the scope of the present invention to permit, for instance, a pre-programmable protocol of movement for the mandrel 312 that is slated to ensure a predetermined wall thickness profile in the tubular product or products being drawn.

[0032] An optional transition section 318 (Figure 3B) of mandrel 312 is preferably dimensioned in such a manner as to facilitate the smooth insertion and extraction of the bearing surfaces of the mandrel 312 and tube 308 while drawing is taking place in the die. As shown, transition section 318 may be frustoconical in shape. Although essentially any angle may be used for this frustoconical shape, an angle of about 30 degrees with respect to the longitudinal axis of the mandrel is believed to produce favorable results.

[0033] Although, in Figures 3A and 3B, a mandrel having two distinct sections (for producing varying wall thicknesses in a final tubular product) is shown, it is to be understood that a mandrel having more than two such sections, possibly up to three or more sections, is conceivable within the scope of the present invention.

[0034] Accordingly, a finished tubular product that is formed with the assembly 300 shown in Figure 3A will be of constant outer diameter. It will be appreciated, then, that the interior surface of tube 308 is varied and deformed through axial movement of mandrel 312, so that the wall thickness is deliberately changed by varying the inner contour of tube 308. The entire outer and inner surfaces of the final tubular product will have a smooth finish, since they will have had positive contact with the inner surface of the die or the outer surface of the mandrel during the drawing process.

[0035] Preferably, in accordance with a preferred embodiment of the present invention, the initial wall of the original tube 308 (from which a final tubular product is to be drawn) will have a wall thickness that is greater than the greatest wall thickness in the final tubular product.

[0036] It is presently contemplated that several other types of adjustments can be undertaken with regard to a die, tube and mandrel, in accordance with at least one presently preferred embodiment of the present invention. Although such possibilities may virtually be limitless, a few examples are illustrated in Figures 4A-4C. Any components in Figures 4A-4C that may be analogous to any components in Figures 3A and 3B bear reference numerals advanced by 100.

[0037] As shown in Figure 4A, an arrangement 424 for discretely adjusting the position of mandrel 412 may be provided in addition to drive 413. In this manner, the position of the mandrel 412 may be discretely adjusted so as to ensure the engagement of the appropriate portion of the mandrel 412 with respect to the die 410 during the drawing process. The discrete adjustment arrangement 424 could be embodied, for example, by one or more devices and/or mechanisms that involve a hydraulic, pneumatic or mechanical force actuator (or any conceivable combination thereof). Mechanisms of these types are generally well-known and thus do not appear to warrant further discussion herein.

[0038] As shown in Figure 4B, it is conceivable, within the scope of the present invention, to induce vibration in die 410, mandrel 412 or tube 408, or any combination of two or more of the three via a suitable vibration inducer 426. Vibration inducer 426 could be embodied, for instance, by an electrical transducer. The objective would be to afford a greater versatility in wall thicknesses and/or shapes associated with tube 408, through reduced frictional resistance resulting from alternating pressure/velocity regimes of lubricant between the various mating surfaces, resulting in a reduction in the drawing force requirement.

[0039] As shown in Figure 4C, it is conceivable to apply electromagnetic induction or another type of heating via a suitable arrangement 428, along an axial or circumferential extent of the tube 408, so as to heat one or more predetermined portions of tube 408 prior to its insertion in die 410. This procedure could potentially modify the properties of the material of tube 408 in order to facilitate greater variability for the wall thicknesses and/or shapes of the final tubular product.

[0040] As discussed heretofore, a mandrel employed in accordance with at least one embodiment of the present invention need not necessarily have cylindrical outer configurations. As shown in Figure 5, at least one

section of an alternative type of mandrel 512 may have a "reverse spline" outer configuration, which itself is adapted to impart an internal spline configuration to a tubular product. Such an internal spline configuration would be suitable, for example, in tubular products that may be used for torque transmission, such as in a steering wheel assembly. Thus, as a starting hollow is drawn over the portion of mandrel 512 shown in Figure 5, an internal spline configuration will ensue that essentially is the reverse of the pattern shown on mandrel 512. In turn, the portion of mandrel 512 may transition to another portion of the mandrel having a different outer configuration, such as a cylindrical or polygonal outer configuration. The transition between the reverse spline portion and the "other" portion would preferably be a smooth transition involving a gentle slope, similar to the transitions between cylindrical mandrel portions as discussed heretofore.

[0041] With regard to all embodiments described heretofore, it is to be understood that, although the foregoing discussion primarily contemplates starting pieces and final tubular products that exhibit radial symmetry with respect to a central longitudinal axis, structural profiles exhibiting radial asymmetry with respect to a central longitudinal axis are also contemplated within the scope of the present invention.

[0042] If not otherwise stated herein, it may be assumed that all components and/or processes described heretofore may, if appropriate, be considered to be interchangeable with similar components and/or processes disclosed elsewhere in the specification, unless an express indication is made to the contrary.

[0043] If not otherwise stated herein, any and all patents, patent publications, articles and other printed publications discussed or mentioned herein are hereby incorporated by reference as if set forth in their entirety herein.

[0044] It should be appreciated that the apparatus and method of the present invention may be configured and conducted as appropriate for any context at hand. The embodiments described above are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is defined by the following claims rather than the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

Claims

1. Method of making a tubular product (100), said method comprising:

providing a starting hollow (308) to be formed into a tubular product (100);
providing a mandrel (312) comprising:

a first section (314) having a first outer configuration; and
a second section (316) having a second outer configuration, said second outer configuration being different from said first outer configuration; and

forming a tubular product (100) from said starting hollow via interaction between said mandrel (312) and said starting hollow (308).

2. The method according to claim 1, wherein said first outer configuration comprises a first dimension (t_1) and said second outer configuration comprises a second dimension (t_2), said second dimension (t_2) being greater than said first dimension (t_1).

3. The method according to claim 1, wherein said first (t_1) and second (t_2) outer dimensions comprise first and second diameters.

4. The method according to claim 1, wherein said first outer configuration corresponds to a first profile in the formed tubular product (100) and said second outer configuration corresponds to a second inner profile in the formed tubular product (100).

5. The method according to claim 4, wherein said first inner profile of the formed tubular product (100) comprises a first wall thickness and said second inner profile of the formed tubular product comprises a second wall thickness, said first wall thickness being greater than said second wall thickness.

6. The method according to claim 1, further comprising:

providing a die (310); and
drawing said starting hollow (308) through said die (310).

7. The method according to claim 6, wherein the formed tubular product has a substantially constant outer contour (D) as a consequence of interaction between said starting hollow (308), said die (310) and said mandrel (312).

8. The method according to claim 6, wherein said forming step comprises displacing said mandrel (312) with respect to said die (310) as said starting hollow (308) is drawn through said die (310) to impart at least two predetermined thicknesses to said starting hollow (308).

9. The method according to claim 2, wherein:

said first and second outer dimensions comprise first and second diameters; and
said mandrel (312) further comprises a transi-

tion section (318) between said first section (316) and said second section (316), said transition section (318) having a varying diameter with said first diameter as a minimum and said second diameter as a maximum.

10. The method according to claim 9, wherein the diameter of said transition section increases between said first diameter and said second diameter.

11. The method according to claim 1, wherein said starting hollow (308) has a wall thickness (t) that is greater than the greatest wall thickness in the formed tubular product (100).

12. The method according to claim 1, wherein said mandrel (312) comprises a third section having a third outer configuration, said third outer configuration being different from said first and second outer configurations.

13. The method according to claim 1, further comprising the step of discretely adjusting the position of said mandrel (312) with respect to said starting hollow (308) prior to said forming step.

14. The method according to claim 1, further comprising the steps of:

providing a die (310);
said forming step comprising inserting said mandrel (312) and said starting hollow (308) into said die (310); and
inducing a vibration in at least one of said mandrel (312), said starting hollow (308) and said die (310) during said forming step.

15. The method according to claim 1, further comprising the step of applying at least one of electromagnetic induction and heating to at least a portion of said starting hollow prior to said forming step to modify at least one property of said starting hollow (308).

16. The method according to claim 1, wherein at least one of said first and second sections exhibits asymmetry with respect to a central longitudinal axis (101) of said mandrel (312).

17. The method according to claim 1, wherein said starting hollow (308) consists essentially of at least one metal material.

18. The method according to claim 1, wherein said starting hollow (308) consists essentially of at least one non-metal material.

19. The method according to claim 18, wherein said starting hollow (308) consists essentially of at least one of the following materials: plastic, fiberglass-reinforced plastic, a reinforced carbon composite and a reinforced plastic composite.

20. The method according to claim 1, wherein said first section (314) of said mandrel (312) and said second section (316) of said mandrel (312) have differing cross-sectional shapes.

21. The method according to claim 1, wherein at lest one of said first and second outer configurations comprises a polygonal configuration.

22. The method according to claim 1, wherein at least one of said first and second outer configurations comprises a reverse spline configuration.

23. Apparatus for making a tubular product (100), said apparatus comprising:

a mandrel (312) for interacting with a starting hollow (308) to be formed into a tubular product (100);
said mandrel (312) comprising:

a first section (314) having a first outer configuration; and
a second section (316) having a second outer configuration, said second outer configuration being different from said first outer configuration.

24. The apparatus according to claim 23, wherein said first outer configuration comprises a first dimension and said second outer configuration comprises a second dimension, said second dimension being greater than said first dimension.

25. The apparatus according to claim 23, wherein said first and second outer dimensions comprise first and second diameters.

26. The apparatus according to claim 23, wherein said first outer configuration corresponds to a first profile in the formed tubular product (100) and said second outer configuration corresponds to a second inner profile in a formed tubular product (100).

27. The apparatus according to claim 26, wherein said first inner profile of the formed tubular product (100) comprises a first wall thickness and said second inner profile of the formed tubular product (100) comprises a second wall thickness, said first wall thickness being greater than said second wall thickness.

28. The apparatus according to claim 23, further comprising:

a die (310) for accepting a starting hollow (308); and

an arrangement for displacing said mandrel (312) with respect to said die (310) as a starting hollow (308) is drawn through said die (310), to impart at least two different thicknesses to the starting hollow (308).

29. The apparatus according to claim 24, wherein:

said first and second outer dimensions comprise first and second diameters; and

said mandrel (312) further comprises a transition section (318) between said first section (314) and said second section (316) said transition section (318) having a varying diameter with said first diameter as a minimum and said second diameter as a maximum.

30. The apparatus according to claim 29, wherein the diameter of said transition section increases between said first diameter and said second diameter.

31. The apparatus according to claim 23, wherein said mandrel (312) comprises a third section (317) having a third outer configuration, said third outer configuration being different from said first and second outer configurations.

32. The apparatus according to claim 23, further comprising an arrangement (424) for discretely positioning the mandrel (312) prior to formation of a tubular product (100).

33. The apparatus according to claim 23, further comprising:

a die (310) for accepting a starting hollow (308); and

a vibration inducer (426) for inducing a vibration in at least one of said mandrel (312), the starting hollow (308) and said die (310).

34. The apparatus according to claim 23, further comprising an arrangement for applying at least one of electromagnetic induction and heating to at least a portion of a starting hollow (308) to modify at least one property of the starting hollow (308).

35. The apparatus according to claim 23, wherein at least one of said first and second sections exhibits asymmetry with respect to a central longitudinal axis (101) of said mandrel (312).

36. The apparatus according to claim 23, wherein said first section (314) of said mandrel (312) and said second section (316) of said mandrel (312) have differing cross-sectional shapes.

37. The apparatus according to claim 23, wherein at least one of said first and second outer configurations comprises a polygonal configuration.

38. The apparatus according to claim 23, wherein at least one of said first and second outer configurations comprises a reverse spline configuration.

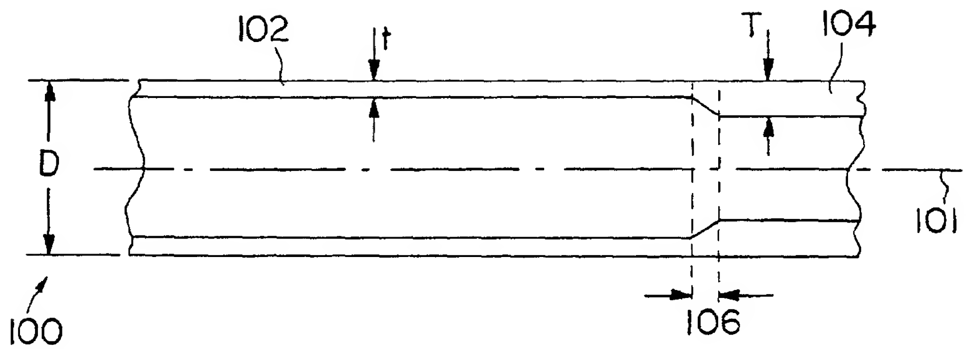
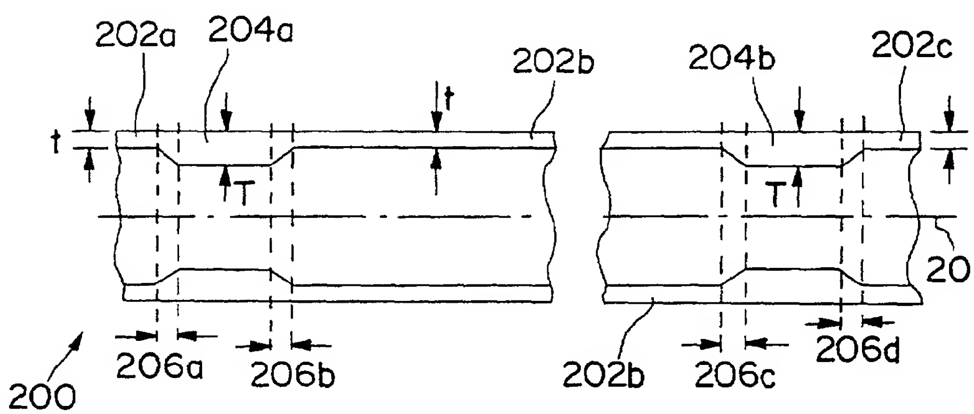

102
t
T
104
D
101
100
106

FIG. 1


202a
204a
202b
204b
202c
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t
T
t
T
t
201
200
206a
206b
202b
206c
206d

FIG. 2

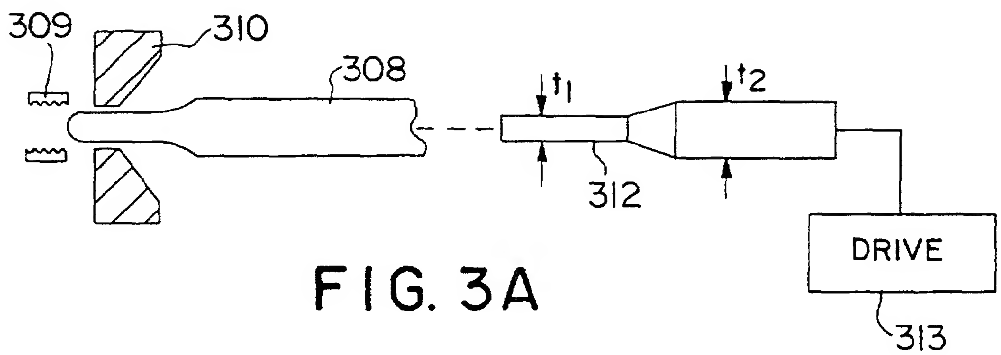

FIG. 3A

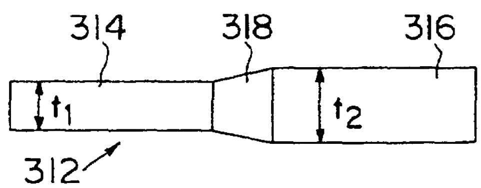

FIG. 3B

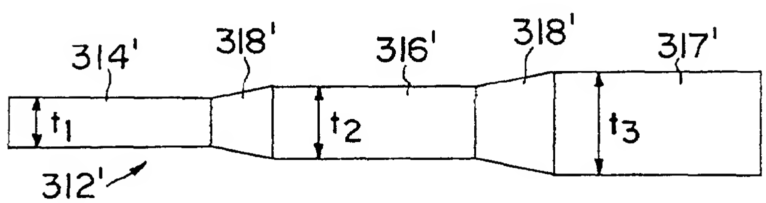

FIG. 3C

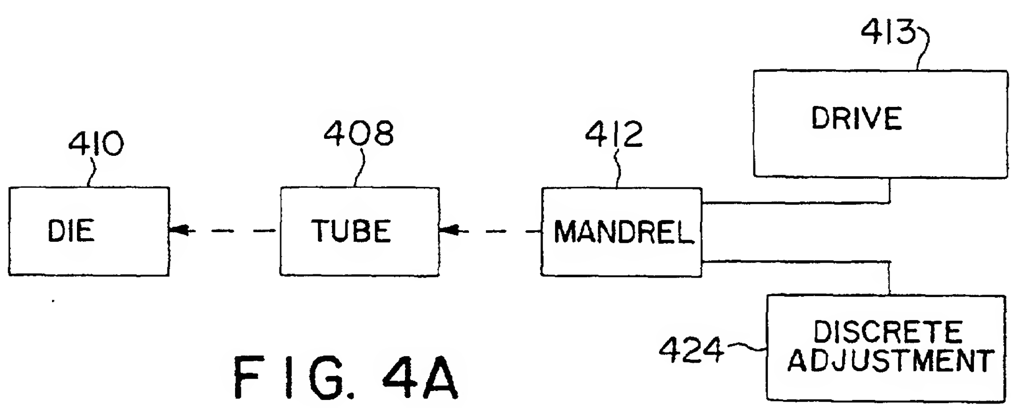

FIG. 4A

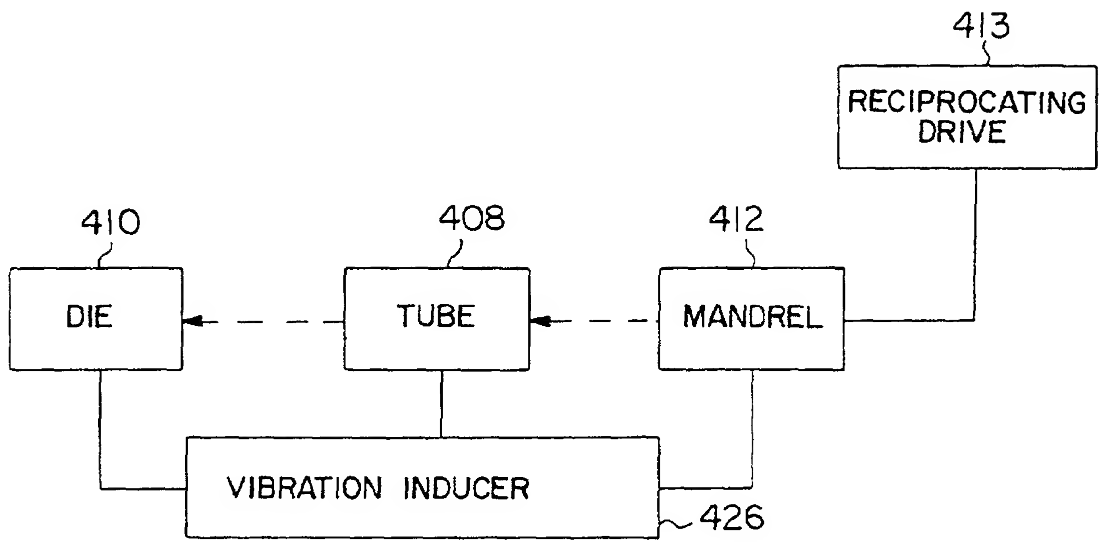
413
RECIPROCATING DRIVE
410
408
412
DIE
TUBE
MANDREL
VIBRATION INDUCER
426

FIG. 4B

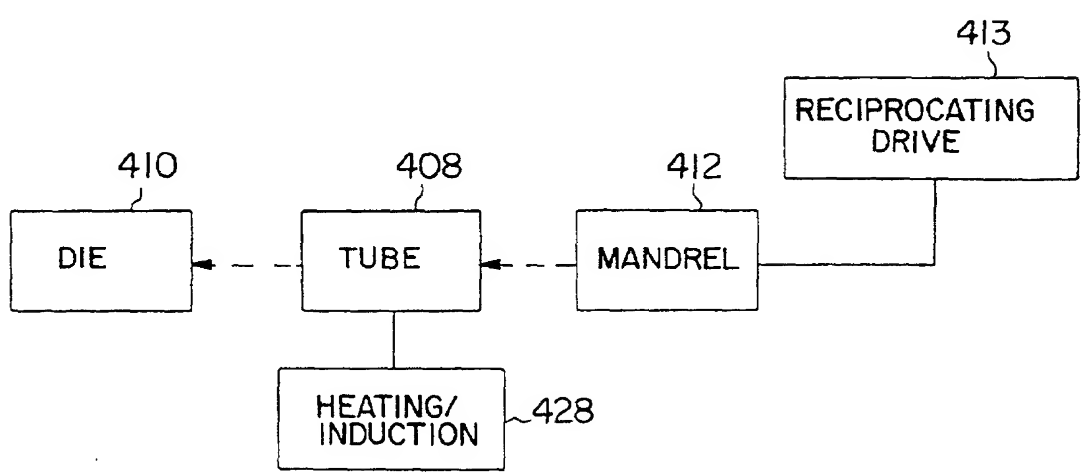
413
RECIPROCATING DRIVE
410
408
412
DIE
TUBE
MANDREL
HEATING/ INDUCTION
428

FIG. 4C

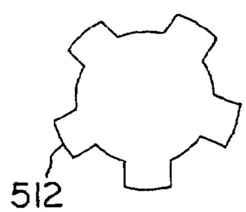

FIG. 5